Fishery Data Series No. 06-39

Evaluation of Rainbow Trout in Koole Lake and Rainbow Lake, 2004

by

April E. Behr

and

Cal Skaugstad

July 2006

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General	
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL
Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_{2}, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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April E. Behr

and

Cal Skaugstad

Alaska Department of Fish and Game, Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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April E. Behr and Cal Skaugstad
Alaska Department of Fish and Game, Division of Sport Fish,
1300 College Road, Fairbanks, AK 99701-1599, USA

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ABSTRACT

The abundance of rainbow trout *Oncorhynchus mykiss* populations at Koole Lake and Rainbow Lake were estimated with two-sample mark-recapture experiments in 2004. Koole Lake and Rainbow Lake are remote lakes located in the Tanana River drainage northwest of Delta Junction and have been stocked with rainbow trout fingerlings since the 1970s. The status of the fish populations was needed to assess current stocking methods and to develop management plans and stocking strategies for both lakes to preserve and improve fishing opportunities for rainbow trout and other stocked species. The Koole Lake fishery is managed under "regional background" regulations while the Rainbow Lake fishery has "special management" regulations.

The estimated abundance for rainbow trout ≥ 240 mm FL in Koole Lake was 1,305 (SE=238). Stocking records indicated that these fish were age 3 and age 5. The fishery management objective for abundance was 1,000 to 2,000 age-2 and older rainbow trout. Rainbow trout captured in Event 2 ranged in size from 245 mm to 442 mm FL, mean length was 350 mm FL (SE = 2.46). The fishery management objective for length-age structure was a mean length ≥ 250 mm FL for age-2 and older rainbow trout.

The estimated abundance for rainbow trout ≥ 347 mm FL in Rainbow Lake was 497 (SE=87). Based on stocking records these fish were age 3 and age 5. The estimated abundance was not significantly different from the fishery management objective of 500 to 1,000 age-2 and older fish. Rainbow trout captured in Event 2 ranged in size from 347 mm to 500 mm FL, mean length was 419 mm FL (SE = 2.64). The fishery management objective for length-age structure was a mean length ≥ 430 mm FL for age-3 and older rainbow trout. The estimated mean length was significantly less than the objective ($p<0.001$).

Management objectives for both rainbow trout populations were based on biennial stockings. However, neither lake was stocked in 2002 or 2003 which resulted in missing age cohorts and fewer fish in the population. For 2005, fishery models based on actual stockings predicted population abundances of approximately 700 and 200 age-2 and older rainbow trout for Koole Lake and Rainbow Lake, respectively. The population abundances for 2005 will not meet the fishery management objectives and may not be adequate to support current harvest levels or catch rates. For 2006, if biennial stocking schedules are followed, the rainbow trout population in Koole Lake should meet abundance and length-age objectives. Rainbow Lake likely will meet the abundance objective in 2006 but the length-age objective will not be achieved until 2007.

Key words: Rainbow Lake, Koole Lake, rainbow trout, *Oncorhynchus mykiss*, abundance, population structure, mean length, stocking history, size-at-age, length-age structure.

INTRODUCTION

Koole Lake and Rainbow Lake produce large rainbow trout (> 400 mm) and both fisheries have become more popular in recent years. Both lakes are remote (Figure 1) and until the mid-1990s access was mostly by aircraft which limited the number of anglers who used these fisheries. Now, increasing numbers of anglers are using snow machines and all-terrain vehicles to get to these lakes.

Anglers who have fished these lakes for several years have reported that the size (length and weight) and number of fish in both lakes have declined recently. Possible reasons for this situation were more anglers were harvesting more fish, the Alaska Department of Fish and Game (ADF&G) was stocking fewer fish, or some combination of both. Another possibility was that fewer stocked fish survived to age-1 (Skaugstad and Fish 2002).

Information about the status of the fish populations in Koole Lake and Rainbow Lake was needed to assess current stocking methods and to develop management objectives and stocking strategies for both lakes that would preserve and improve fishing opportunities for rainbow trout and other stocked species.

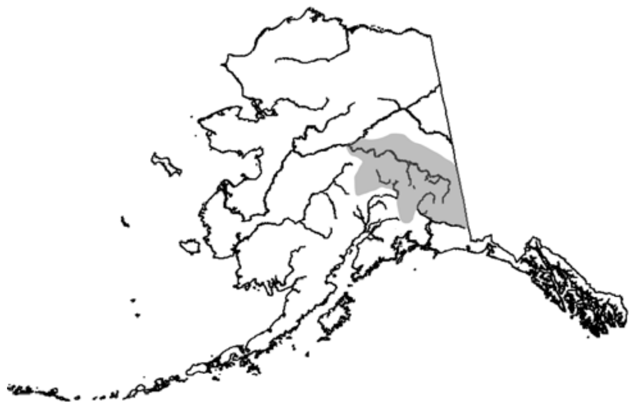

Figure 1.–The Tanana River and Upper Copper/Upper Susitna River drainages (shaded area).

EVALUATION OF RAINBOW TROUT IN KOOLE LAKE

Koole Lake is approximately 12 km South of Birch Lake (Figure 2). The lake covers 130 surface ha and it has been stocked with rainbow trout since 1974. Approximately 16,000 to 32,000 rainbow trout fingerlings were stocked into Koole Lake every year up to 1999 (Appendix A). After 1999 Koole Lake and other remote lakes were scheduled for stocking every other year. The goal was to reduce the cost of stocking remote lakes and sustain the fisheries. In 2003 the stocking schedule for Koole Lake was changed from odd years to even years to balance annual hatchery production. As a consequence the lake was not stocked with rainbow trout in 2002 or 2003. Currently, Koole Lake is scheduled for biennial stockings of 24,500 fingerling (~2 g) rainbow trout. From 1998 through 2002, the 5-year averages for catch and harvest were about 2,164 and 721 rainbow trout, respectively.

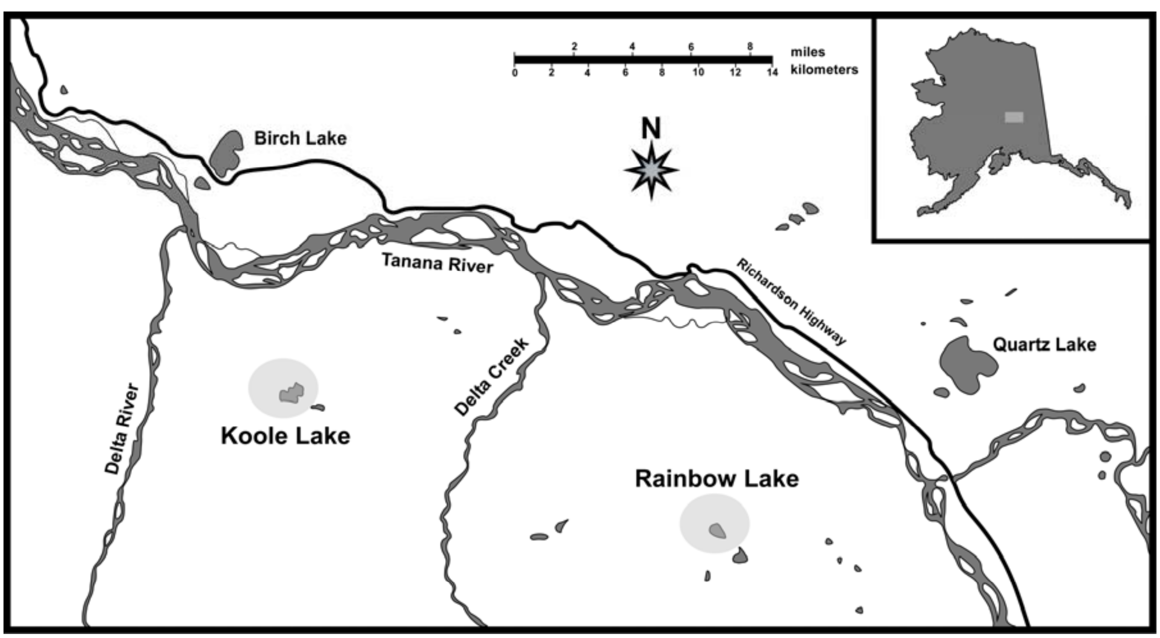

Figure 2.–Location of Koole Lake and Rainbow Lake, Tanana River drainage.

OBJECTIVE

The objective of this project was to estimate the abundance of rainbow trout in Koole Lake that were stocked prior to 2004 such that the estimate was within ±35% of the true value 95% of the time.

METHODS

The population abundance of rainbow trout in Koole Lake was estimated using two-sample mark-recapture techniques for a closed population (Seber 1982). Rainbow trout were captured and marked from 7 through 11 June (Event 1). Fish were again captured from 1 through 10 September (Event 2) and examined for marks. Water temperature was measured 0.5 m below the surface each day at 1400 hours.

Sampling Procedure

Koole Lake was divided into three areas to distribute sampling effort and to aid in diagnostic testing of the assumptions intrinsic to two-sample mark-recapture estimators (Seber 1982; Figure 3). Because different size fish may behave differently during the experiment, multiple gear types were used to sample various habitats. Two fyke nets were set in each area and checked once a day. After a net was checked it was moved to another location within the same area. All fyke nets were set near shore on the lake bottom in approximately 1 to 2 m of water. The body of each fyke net was positioned parallel to shore. Fyke nets were ~5 m long, the open square end of each net measured 0.9 m on edge, trailing hoops were 0.9 m diameter, and mesh size was 9 mm^2. Leads (or "wings") were attached to both sides of the open end and measured 7.5 m long by 1.2 m deep. The wings were set to form a "V". One wing was anchored to shore, and a weight was attached to the other wing and positioned offshore. The cod end of each fyke net was pulled taunt and a weight was attached to prevent the fyke net from collapsing. If weather conditions were windy, 12.7 mm x 1.5 m pieces of conduit were driven into the ground, in place of weights, to secure the nets.

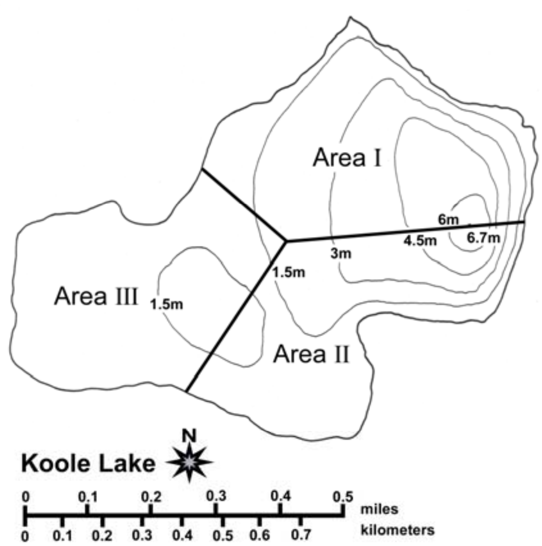

Figure 3.–Sampling areas for Koole Lake mark-recapture study, 2004.

During the second event one tangle net measuring 45 m long by 5.4 m deep was used away from shore in water deeper than 2 m. The tangle net was used only during Event 2 because fish were more likely to be injured with this gear which could affect the likelihood of recapture during subsequent capture events. The net was checked every 30-45 min and moved to a new location after each check. Mesh size was small, 13 mm (½ in) bar fine thread monofilament, to ensure that fish were captured by entanglement around the mouth and not by the gill covers.

Sport fishing gear was used during both sampling events to catch fish in areas not accessible with fyke nets or tangle nets. Terminal gear included flies and lures with barbless hooks.

All fish captured during both events were measured to the nearest millimeter FL and examined for marks. Any unmarked fish was marked as specified in the marking schedule described below. To facilitate processing, the fish were partially anesthetized with a concentration of 50 mg/l clove oil. After the fish were removed from the anesthesia they quickly recovered and swam away within several minutes. Any fish that showed signs of severe stress during the first event was released unmarked.

Fish captured during the first event were given two marks. All fish were marked by completely excising the adipose (AD) fin. A second mark to identify the sampling area where the fish was captured was made by injecting red photonic pigment into fin ray interstitial spaces. Fish caught in Area I, Area II, or Area III were marked in the left ventral (LV) fin, right ventral (RV) fin, or the anal (AN) fin, respectively. Fish captured multiple times in the first event were not given additional marks. The photonic pigment marks were made with a BMX1000 SuperMICRO-Ject™[1] manufactured by New West Technologies, Santa Rosa, CA.

Fish captured during the second event were marked by removing a small portion of tissue from the trailing edge of the upper lobe of the caudal fin (UC - upper caudal clip). The fin clip removed approximately 5 mm of tissue from the tip of the fin lobe and produced a clean-cut edge that was readily distinguishable. Fish captured during the second event were not marked with red pigment and there was no differential marking between gear types or areas. Fish captured multiple times during the second event were not given additional marks.

Any fish injected with red pigment and had its adipose fin excised during Event 1 was classified as “marked.” Any fish captured during Event 1 with a red pigment mark, a missing adipose fin, or both was classified as “captured more than once during the first event.” Any fish captured during Event 1 that had a missing adipose fin but no red pigment mark was classified as a “lost mark”. Any fish captured during Event 2 with a red pigment mark and an adipose fin clip was classified as “recaptured” (captured in the first and second events) and the location of the red pigment mark was recorded (LV, RV, and AN). Any fish captured in Event 2 with no mark was classified as “unmarked” (captured for the first time). Any fish captured during Event 2 that had a missing adipose fin but no red pigment mark was classified as “recaptured” and “lost mark”. Any fish captured during Event 2 that had both an adipose clip and caudal clip but had no red pigment mark was classified as “lost mark” and “recaptured more than once.” Any fish captured during Event 2 with an upper caudal clip was classified as “captured more than once during the second event.” Fish captured more than once during either event were noted but were not used to estimate abundance.

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[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

Data were recorded on field data sheets specifying lake name, date, gear type, trap/net number, location (Area I, II, or III), species, length, type of pigment mark (LV, RV, or AN) and fin mark (AD and UC). After field work was completed all data were transferred to Microsoft Excel[2] spreadsheets, edited twice for errors, analyzed, and archived (Appendix B).

Assumptions for a Two-Sample Mark-Recapture Experiment

The assumptions necessary for accurate estimation of abundance in a closed population were as follows (Seber 1982):

1. The population was closed (no change in the number of rainbow trout in the population during the estimation experiment; i.e., there was no immigration, emigration, births or deaths);
2. All rainbow trout had the same probability of capture in the marking sample or in the recapture sample, or marked and unmarked rainbow trout mixed completely between marking and recapture events;
3. Marking rainbow trout did not affect their probability of capture in the recapture sample;
4. Rainbow trout did not lose their mark between the marking and recapture events; and,
5. All marked rainbow trout were reported when recovered in the recapture sample.

For Assumption 1, no immigration or emigration was assured because the lake did not have inlets or outlets. No births occurred because rainbow trout do not reproduce in this lake. Some losses due to natural mortality and harvest likely occurred between sampling events, however marked and unmarked fish were expected to be subject to similar rates of loss. As such, the abundance estimate was germane to the time of Event 1.

Assumption 2 was evaluated with respect to size selective sampling and capture probabilities that varied with location using diagnostic procedures described in Appendix C1 and Appendix C2. The sampling design increased the likelihood that one or more of the conditions of Assumption 2 were met. Multiple gear types were used and various habitats were sampled to increase the chance that all fish had a similar probability of capture. Marked and unmarked fish mixed for almost three months between events and fish handled during both events were released toward the middle of the lake.

To minimize the likelihood of higher mortality rates for marked fish (Assumption 3), all captured fish were handled carefully and all anesthetized fish were placed in a holding pen for recovery and observation before being released. Tangle nets were used only during Event 2 because this capture method was more likely to result in some injury to fish. During Event 1 any fish that showed signs of severe stress was released but was not marked. The hiatus between capture events also allowed time to minimize any lingering behavioral responses to the capture gear.

Assumption 4 was assured because all fish were given a permanent secondary mark by completely excising the adipose fin. It was unlikely that a properly excised adipose fin would regenerate. If a pigment mark was lost during the experiment then a missing adipose fin would identify a fish as having been captured in Event 1. Assumption 5 was assured because all fish were rigorously examined for pigment marks and adipose fins.

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[2] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

Water temperature was monitored during this experiment because other studies suggested that larger rainbow trout were more likely to avoid shallow water (< 2 m deep) at temperatures near and exceeding 20°C. This behavior could violate one of the conditions for Assumption 2. Also, captured fish were stressed more by temperatures ≥ 20°C and were less likely to recover from handling during sampling and marking procedures. This situation would violate Assumption 3. Typically, in some lakes in the Tanana Valley, the temperature in shallow water was ≥ 18°C from mid June through mid August and water temperature usually exceeds 20°C during July. To ensure that Assumptions 2 and 3 were not violated, when water temperature exceeds or will likely exceed 18°C 1 m below the surface during sampling, the experiment will be postponed.

Chapman's modification of the Petersen estimator (Chapman 1951; Seber 1982) was used to estimate the abundance of the rainbow trout population:

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \tag{1}$$

where:

$\hat{N}$ = the abundance of rainbow trout;

n_1 = the number of rainbow trout marked and released during Event 1;

n_2 = the number of rainbow trout examined for marks during Event 2; and,

m_2 = the number of rainbow trout marked during Event 1 that were recaptured during Event 2.

Variance of Chapman's modified estimator was calculated using (Seber 1982; Wittes 1972):

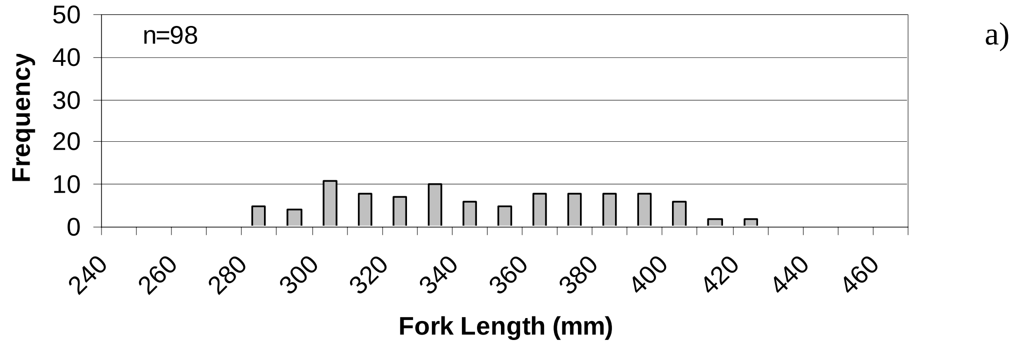
$$V\left[\hat{N}\right] = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)}. \tag{2}$$

RESULTS AND DISCUSSION

During Event 1, 98 rainbow trout were captured, marked, and released (Figure 4a). During Event 2, 276 rainbow trout were captured and examined for marks, 20 of which were recaptured (Figure 4b). Rainbow trout captured during Event 2 ranged in size from 245 to 442 mm FL, mean length was 350 mm FL (SE = 2.46). During the experiment, 8 of the 20 recaptured fish had lost their pigment mark.

Plots of cumulative frequency distributions (CFDs) were generated from lengths of fish captured during both events (Figure 5). Test results for size selectivity (Appendix C1) indicated that there was no significant size bias during Event 1 (D=0.175, P=0.589) and stratification by size was not required prior to estimating abundance.

Test results for consistency of capture probabilities detected no evidence of heterogeneity during Event 2 (χ^2 = 1.8, P = 0.41; Table 1). However, there was some evidence indicating potential variability in the probability of capture during Event 1 (χ^2 = 5.0, P = 0.08). The test for complete mixing was not valid because some cells had expected values less than 1. The results from Event 2 were sufficient to conclude that a Petersen type estimator was appropriate for estimating abundance. Data were pooled and a single, unstratified estimator was used to estimate an abundance of 1,305 (SE=238) rainbow trout ≥ 240 mm in Koole Lake.



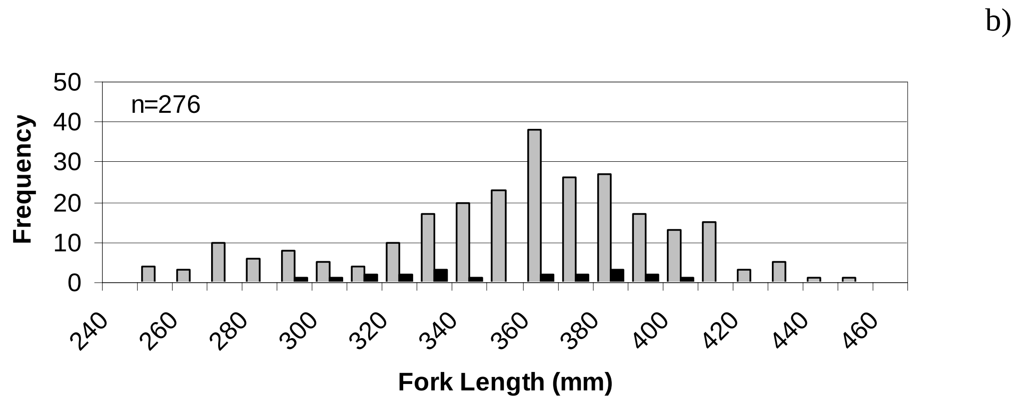


Figure 4.–Lengths of rainbow trout ≥ 240 mm captured during Koole Lake mark-recapture experiment, 2004; a) Event 1 or marking event and b) Event 2 or recapture event, with recaptures (n=20) shown in black.

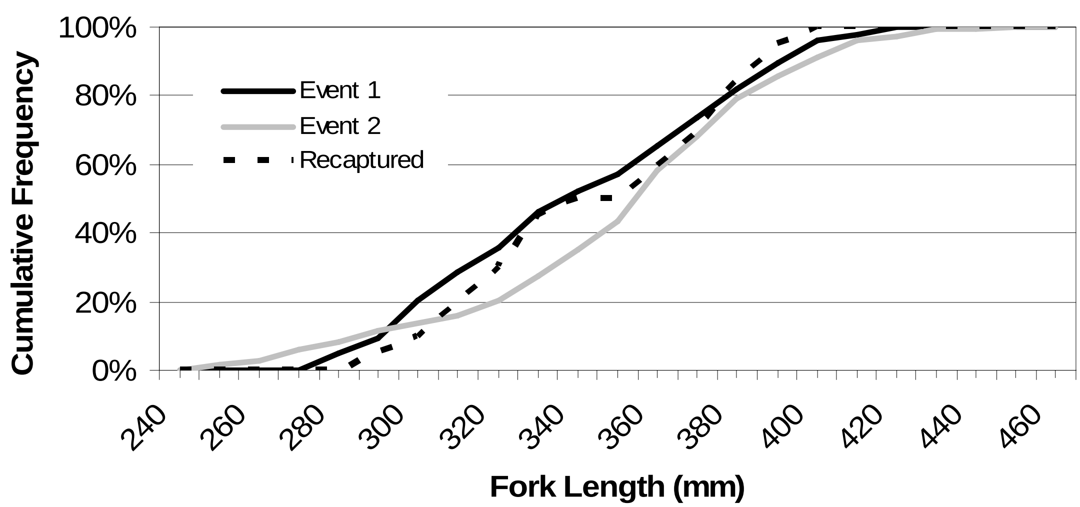


Figure 5.–Cumulative frequency distributions of lengths for rainbow trout ≥ 240 mm FL captured during the mark-recapture experiment at Koole Lake, 2004.

Table 1.–Contingency table analysis by capture location for rainbow trout ≥240 mm caught at Koole Lake, 2004.

Test for equal probability of capture among areas during Event I

	Area Examined			Test Results	
	I	II	III		
				χ^2	5.01
Marked (m2)	1	10	9	df	2
Unmarked (n2-m2)	68	86	102	P	0.08

Test for equal probability of capture among areas during Event II

	Area Marked[a]			Test Results	
	I	II	III		
				χ^2	1.8
Recaptured (m2)	2	5	5	df	2
Not Recaptured (n1-m2)	29	23	34	P	0.41

Mixing among areas between Events I and II (presented for additional information)

	Area Recaptured			
Area Marked[a]	I	II	III	(n1-m2)
I	0	2	0	29
II	1	3	1	23
III	0	3	2	34

[a] Area where marked could not be determined for some recaptured fish due to loss of pigment marks. The number of recaptured fish listed (m2) represents the number of fish that had a pigment mark. This is less than actual number of recaptured fish that had and adipose mark.

n1 - Fish captured during Event 1.

n2 - Fish captured during Event 2.

m2 - Fish marked during Event 1 and recaptured during Event 2.

Between Event 1 and Event 2, Koole Lake was stocked with approximately 18,000 rainbow trout fingerlings (48 mm mean FL); 919 rainbow trout subcatchables (104 mm mean FL); 1,156 coho salmon fingerlings (64 mm mean FL; and 1,000 Arctic char (*Salvelinus alpinus*) subcatchables (132 mm mean FL) (Appendix A). These fish were not part of the mark-recapture experiment and they were readily distinguished from rainbow trout ≥ 240mm FL.

Water temperature during Event 1 reached 14°C 0.3 m below the surface. Project biologists expected that the temperature in shallow water would likely reach or exceed 20°C during Event 2 if it occurred as originally scheduled from 16 to 20 June. Consequently, Event 2 was delayed until September.

EVALUATION OF RAINBOW TROUT IN RAINBOW LAKE

Rainbow Lake is about 16 km Southwest of Quartz Lake near Delta Junction (Figure 6). The lake surface area is 39 ha and it has been stocked with rainbow trout since 1971 (Appendix A). The stocking schedule for Rainbow Lake has been erratic. Stockings of rainbow trout fingerlings have varied from consecutive years to once in 4 years. The number of fish stocked each time has also varied from 7,000 to over 59,000. After 1999, the lake was scheduled for stocking every other year. The stocking schedule, however, was changed in 2003 from odd years to even years to accommodate hatchery production schedules. The lake was not stocked in 2002 or 2003. Presently, Rainbow Lake is scheduled for biennial stockings of 8,600 fingerling (~2 g) rainbow trout. The 5-year averages for catch and harvest from 1998 through 2002 were about 831 and 250 rainbow trout, respectively.

OBJECTIVES

The objective of this study was to estimate the abundance of all rainbow trout in Rainbow Lake such that the estimate is within ±35% of the true value 95% of the time.

METHODS

The population abundance of rainbow trout in Rainbow Lake was estimated following the same procedures outlined in the preceding section of this report, *Evaluation of Koole Lake Rainbow Trout* with the following exceptions:

Rainbow trout were captured and marked in Event 1 from 24 through 28 August using fyke nets and hoop traps. During Event 2, fish were again captured and examined for marks from 13 through 16 September using fyke nets, hoop traps, tangle nets, and hook and line gear.

Sampling areas for Rainbow Lake were nearshore (< 3 m deep; Areas I and II) and offshore (≥ 3 m deep; Area I; Figure 6). During both sampling events three fyke nets were used in Areas I and II and three hoop traps were used in Area III.

Hoop traps were suspended at various depths in the water column and randomly positioned within the area. Hoop traps were cylindrical, 0.5 m diameter by 1.6 m long, with inward pointing conical funnels at each end having 125 mm openings. Netting was 6.4 mm Delta weave. Each hoop trap was baited with unsalted salmon roe, attached to a vertical line, and oriented with the long axes of the hoop trap parallel to the water surface. Each time a hoop trap was checked it was moved to a new location within Area III.

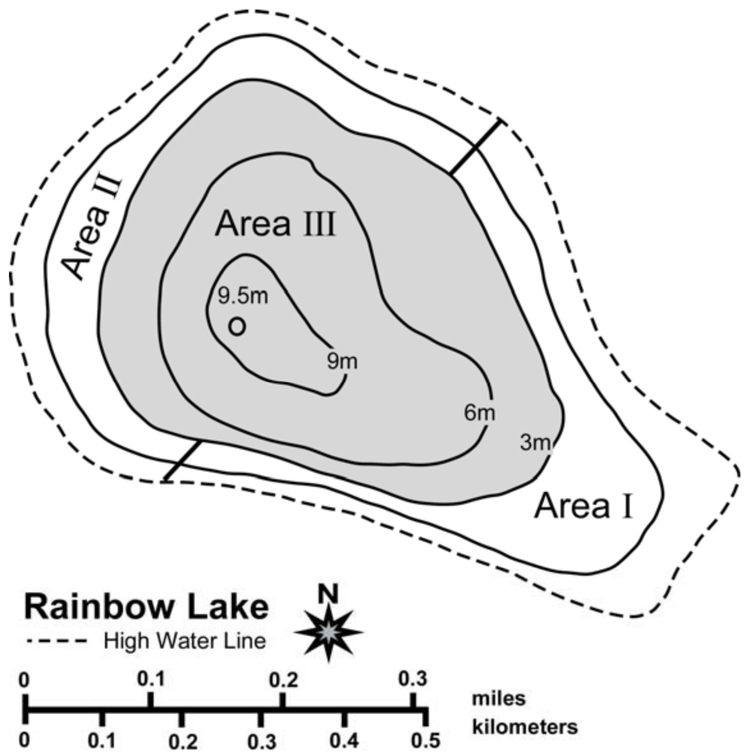
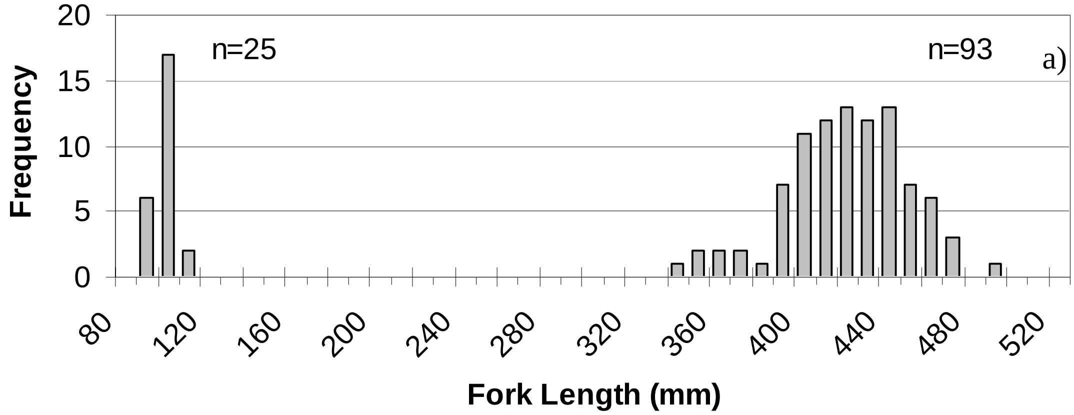


Figure 6.–Sampling areas for Rainbow Lake mark-recapture study, 2004.

RESULTS AND DISCUSSION

Fish captured during both sampling events in Rainbow Lake ranged in size from 84 mm to 500 mm FL (Figures 7a and 7b). However, 75 of these fish were stocked in 2004 and were not part of the mark-recapture experiment. This experiment was only concerned with fish stocked prior to 2004. During Event 1, 93 rainbow trout were captured, marked, and released (Figure 7a). During Event 2, 105 rainbow trout were captured and examined for marks, 19 of which were recaptured (Figure 7b). Age-2 and older rainbow trout captured in Event 2 ranged in size from 347 mm to 500 mm FL, mean length was 419 mm FL (SE=2.64).

All recaptured fish had a pigment mark and no adipose fin. The retention rate for the pigment mark was better at Rainbow Lake compared to that for Koole Lake. However, the hiatus between capture events at Rainbow Lake was 2 weeks compared to almost 3 months at Koole Lake. One possible explanation was that the retention rates were similar over time and the observed difference was due to dissimilar hiatus durations. Another possibility was that the crew at Rainbow Lake was more experienced and produced better, longer-lasting pigment marks.



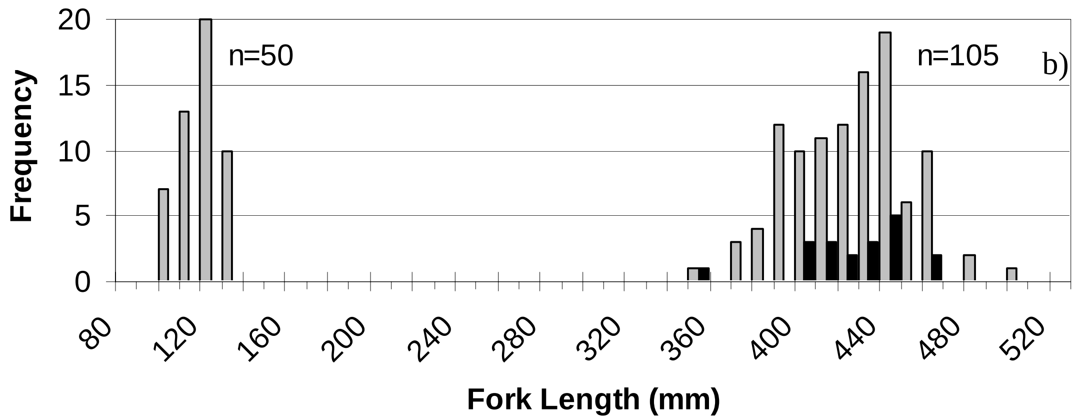


Figure 7.–Lengths of rainbow trout captured during Rainbow Lake mark-recapture experiment, 2004; a) Event 1 or marking event and b) Event 2 or recapture event, with recaptures (n=19) shown in black.

Plots of CFDs were generated from lengths of fish captured during both sampling events (Figure 8). Test results (Appendix C1) indicated that there was no significant size bias during Event 1 (D=0.147, P=0.834). Results from tests of consistency indicated that the probability of capture was similar for all fish during Event 1 and Event 2 (Table 2). The test for complete mixing was not valid because some cells had expected values less than 1. Based on these diagnostic tests, we concluded that Assumption 2 was valid because at least one of the three conditions was met. Therefore, data were pooled and a single, unstratified estimator was used to estimate an abundance of 497 (SE=87) rainbow trout ≥ 347mm FL in Rainbow Lake.

The water temperature 0.5 m beneath the surface on 25 August and 26 August was 17.7°C and 16.3°C, respectively. After 26 August the thermometer stopped working but the temperature continued to cool during the remainder of the experiment.

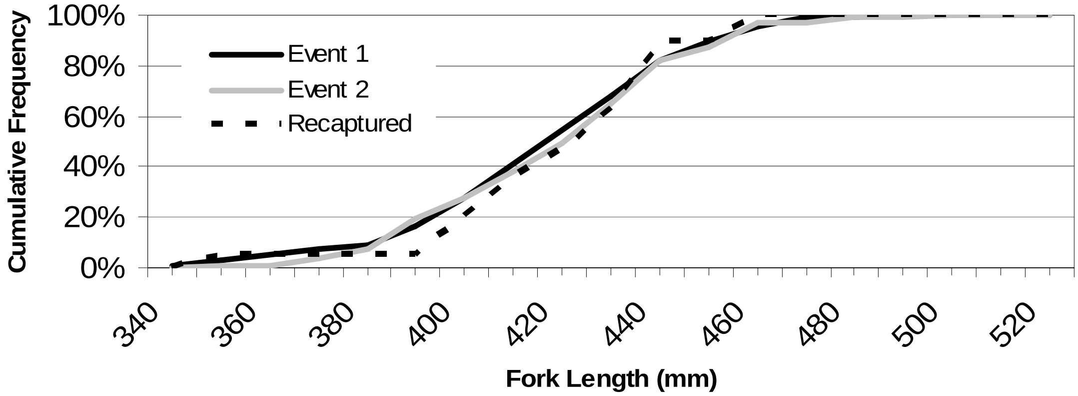


Figure 8.–Cumulative frequency distribution of lengths from rainbow trout ≥347mm FL captured during the mark-recapture experiment at Rainbow Lake, 2004.

Table 2.-Contingency table analysis by capture location for rainbow trout ≥347mm caught at Rainbow Lake, August 25-28 and September 14-16, 2004.

Test for equal probability of capture among areas during Event I

	Area Examined			Test Results	
	I	II	III		
				χ^2	1.06
Marked (m2)	9	10	0	df	2
Unmarked (n2-m2)	33	50	3	P	0.59

Test for equal probability of capture among areas during Event II

	Area Marked			Test Results	
	I	II	III		
				χ^2	1.09
Recaptured (m2)	6	13	0	df	2
Not Recaptured (n1-m2)	31	41	1	P	0.58

Mixing among areas between Events I and II

	Area Recaptured			
Area Marked	**I**	**II**	**III**	**(n1-m2)**
I	4	5	0	31
II	2	8	0	41
III	0	0	0	1

n1 - Fish captured during Event 1.
n2 - Fish captured during Event 2.
m2 - Fish marked during Event 1 and recaptured during Event 2.

MANAGEMENT IMPLEMENTATION

KOOLE LAKE

The Koole Lake fishery was managed under "regional background" regulations where the general management objective was to create and maintain a fishery that provides for a reasonable expectation of catching the daily bag limit within a day's angling. The daily bag and possession limit was 10 fish, all species combined, of which only 1 fish can be ≥ 18 inches (457 mm) total length.

A model of the Koole Lake rainbow trout population indicated that an annual abundance of 1,000 to 2,000 age-2 and older rainbow trout was needed to sustain this fishery. The desired length-age objective was a mean length ≥ 250 mm FL for the portion of the population age-2 and older. The model used length-age, survival, and harvest data from this and other population sampling projects. It showed that biennial stockings of 24,500 rainbow trout fingerlings (2 g) would achieve the objectives for population structure (abundance and length-age) for the current annual harvest level.

The rainbow trout population structure in 2004 met the objectives for abundance and length age. However, for 2005, the expected population abundance based on actual stockings would be about 700 age-2 and older rainbow trout. A population of 700 rainbow trout will not meet the objective for abundance and it probably will not be adequate to support current harvest levels or catch rates. The predicted low abundance was likely the consequence of not stocking the lake in 2002 or 2003 while adjusting to a new stocking schedule. In 2006 the rainbow trout population should meet management objectives for abundance and length-age.

However, if the popularity of the fishery continues to increase and the harvest also increases, the current management objectives may not be achieved. ADF&G needs to closely monitor the rainbow trout population structure (abundance and length-age) and take appropriate actions so that the fishery remains attractive to anglers.

There are actions that ADF&G can take to increase the abundance of rainbow trout or to reduce harvest. One action is to stock more rainbow trout, or stock additional species, but this probably will not produce sufficient numbers of large fish that attracts anglers to Koole Lake. The mean lengths for the different age cohorts could become smaller because more fish are competing for limited resources. Having more but smaller fish might make the fishery less attractive.

Another action is to reduce the daily bag limit with the goal of maintaining the annual harvest at the current level. If harvest does not increase, then the current stocking schedule would likely maintain the current population structure for abundance and length-age. The daily bag limit can be reduced by moving Koole Lake to the "conservative" management category where the daily bag limit is 5 fish, all species combined, of which only 1 fish can be ≥ 18 in (457 mm) total length.

Under "regional background" regulations, consistent stocking would help to increase and maintain the number of rainbow trout in the population.

Recommended actions:

- Biennial stockings of 24,500 fingerling (2 g) rainbow trout. The goal is to provide a consistent and predictable population structure (abundance and length-age) by adhering to a stocking schedule.

- Assess the population structure (abundance and length-age) in 2008. The goal is to determine if the current stocking methods and fishing regulations are meeting the fishery management objectives.
- Experiment with fish culture methods to produce rainbow trout fingerlings for stocking by mid-June. The goal is to increase the survival and growth rates of rainbow trout and to lower the cost of maintaining the fishery.

RAINBOW LAKE

In spring 2004 the Board of Fisheries placed Rainbow Lake into a "special management" category where the general management objective was to maintain a high probability of catching several large fish (> 18 in, 457 mm total length) during a day's angling for an experienced angler. The daily bag and possession limit was 1 fish ≥ 18 inches (457 mm) total length. Before the regulations for "special management" took effect in spring 2004, the daily bag and possession limit for rainbow trout was 10, no size restriction.

Population modeling showed that this fishery, where the intent was to limit harvest in order to produce and maintain a relatively high number of large fish, required an abundance between 500 and 1,000 age-2 and older rainbow trout. The objective for length-age structure was a mean length ≥ 430 mm FL for the portion of the population age-3 and older. The model indicated that biennial stockings of 8,600 rainbow trout fingerlings (2 g) were sufficient to achieve the objectives for abundance and length-age for the current harvest level.

The rainbow trout population met the abundance objective for 2004 but the length-age objective was not met. The difference, however, was about 11 mm and likely not meaningful to anglers. For 2005 the expected abundance of age-2 and older rainbow trout would be about 200. This population likely will not provide sufficient numbers of large fish to sustain current catch rates. The likely reason for the low abundance was the same as that for Koole Lake – fish were not stocked in 2002 or 2003. In 2006 the rainbow trout population should meet the objective for abundance but the length-age objective likely will not be met until 2007.

Because regulations and management objectives for the Rainbow Lake fishery have changed, the fish population structure (abundance and length-age) likely will change over the next few years. The rainbow trout population should be monitored occasionally over the next several years to determine if the regulation changes are having the desired effect on the population abundance and length-age.

Recommended actions:

- Biennial stockings of 8,600 fingerling (2 g) rainbow trout. The goal is to provide a consistent and predictable population structure (abundance and length-age) by adhering to a stocking schedule.
- Assess the population structure (abundance and length-age) in 2008 and 2011. The goal is to determine if the current stocking methods and fishing regulations are meeting the fishery management objectives.
- Experiment with fish culture methods to produce rainbow trout fingerlings for stocking by mid-June. The goal is to increase the survival and growth rates of rainbow trout and to lower the cost of maintaining the fishery.

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APPENDIX A
STOCKING HISTORY FOR KOOLE LAKE AND RAINBOW LAKE, 1999-2004

Appendix A.–Recent stocking history for Koole Lake and Rainbow Lake, 1999-2004.

Koole Lake

Species	Hatchery	Brood Source	Date	Number Stocked	Length (mm)	Weight (g)
Rainbow Trout	SCHC	Swanson River	22-Aug-99	16,550	63	2.33
Rainbow Trout	SCHC	Swanson River	8-Aug-01	20,000	45	0.80
Rainbow Trout	SCHC	Swanson River	18-Jun-04	919	104	11.65
Rainbow Trout	SCHC	Swanson River	14-Jul-04	18,000	48	0.95
Coho Salmon	SCHC	Bear Lake	19-Jul-04	1,156	63	2.33

SCHC = Ship Creek Hatchery Complex Anchorage, Alaska.

Rainbow Lake

Species	Hatchery	Brood Source	Date	Number Stocked	Length (mm)	Weight (g)
Rainbow Trout	SCHC	Swanson River	26-Jul-99	7,000	53	1.32
Rainbow Trout	SCHC	Swanson River	8-Aug-01	8,600	45	0.80
Rainbow Trout	SCHC	Swanson River	14-Jul-04	12,000	48	0.95

SCHC = Ship Creek Hatchery Complex Anchorage, Alaska.

APPENDIX B
ARCHIVED DATA FILES

Appendix B.–Archive files for data collected during studies covered in this report.

File Name [a]
Koole Lake Mark-Recapture Data 2004.xls
Rainbow Lake Mark-Recapture Data 2004.xls

[a] Data files are archived at and are available from the Alaska Department of Fish and Game, Division of Sport Fish, 1300 College Road, Fairbanks, Alaska 99701-1599.

APPENDIX C
TESTS OF SIZE SELECTIVITY AND CONSISTENCY FOR PETERSEN ESTIMATOR

Appendix C1.–Tests of size selectivity for Petersen Estimator.

TEST OF SIZE SELECTIVITY IN PETERSEN ESTIMATOR

Size selective sampling was tested with a two sample Kolmogorov-Smirnov (K-S) test (Conover 1980) generated from length data collected during the marking and recapture events (Appendix B). Lengths of fish captured during Event 2 were tested against lengths of fish marked in Event 1 and recaptured during Event 2.

H_o for this test is: The distribution of lengths for fish recaptured during Event 2 is the same as the distribution of lengths for all fish captured during Event 2.

If no significant difference was detected between these two samples equal probability of capture in Event 1 was indicated and all data were pooled to calculate one unstratified population estimate. If a significant difference was detected, it was assumed that a size stratified estimator was required because no robust testing procedure is available to evaluate size selective sampling during Event 2. Data from both sampling events would be stratified into two or more size strata such that no significant difference was detectable when the K-S test described above is repeated within strata. Abundance would then be estimated for each size stratum and the estimates and variances would be summed for an overall abundance estimate. Size composition parameters would be estimated for each stratum, and then combined weighted by estimated abundance in each stratum. This decision protocol for stratification is conservative, in that stratification may be used when it is actually unnecessary due to equal probability of sampling during Event 2. However, the loss in precision from using stratified estimation when it is unnecessary is relatively small, and potential bias due to size bias sampling is prevented.

Appendix C2.–Tests of consistency for Petersen Estimator.

TESTS OF CONSISTENCY FOR PETERSEN ESTIMATOR

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-squared statistic was used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis must be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a geographically stratified estimator (Darroch 1961) would be used to estimate abundance.

I.-Test for complete mixing [a]

Area/Time	Area Where Recaptured				Not Recaptured
Where Marked	**1**	**2**	**…**	**t**	(n_1-m_2)
1					
2					
…					
s					

II.-Test for equal probability of capture during the first event [b]

	Area Where Examined			
	1	**2**	**…**	**T**
Marked (m_2)				
Unmarked (n_2-m_2)				

II.-Test for equal probability of capture during the second event [c]

	Area Where Marked			
	1	**2**	**…**	**S**
Recaptured (m_2)				
Not Recaptured (n_1-m_2)				

[a] This tests the hypothesis that movement probabilities (θ) from area i (i = 1, 2, ...s) to section j (j = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among area designations: H_0: $\Sigma_i a_i \theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among area designations: H_0: $\Sigma_j \theta_{ij} p_j$ = d, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.